9 Controls, Indications and Alerts

The human-machine interface with the FGS is key to ensuring safe, effective and consistent FGS operation. The manner in which FGS information is depicted to flight crews is essential to the flight crew awareness, and therefore, the safe operation of the FGS.

The controls, indications, and alerts should be so designed as to minimize flight crew errors and confusion. Indications and alerts should be presented in a manner compatible with the procedures and assigned tasks of the flight crew and provide the necessary information to perform those tasks. The indications should be grouped and presented in a logical and consistent manner and be visible from each pilot's station under all expected lighting conditions. The choice of colors, fonts, font size, location, orientation, movement, graphical layout and other characteristics such as steady or flashing should all contribute to the effectiveness of the system. Controls, indications, and alerts should be implemented in a consistent manner.

It is recommended that the applicant evaluate the adequacy and effectiveness of the information provided by the FGS interface (i.e., controls, indications, alerts, and displays) to ensure flight crew awareness of FGS behavior and operation. See Section 14, Compliance Demonstration using Flight Test and Simulation, for more discussion of appropriate analyses (which may include, for example, cognitive task analysis as a basis for evaluation).

9.1 FGS Controls

The FGS controls should be designed and located to provide convenient operation to each crew member and to prevent crew errors, confusion and inadvertent operation. To achieve this, §/JAR 25.1329 (f) requires that command reference controls to select target values (e.g., heading select, vertical speed) should operate as specified in §/JAR 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control should be readily apparent or plainly indicated on, or adjacent to, each control if needed to prevent inappropriate use or confusion. §/JAR 25.781 also provides requirements for the shapes of the knobs. The design of the FGS should address the following specific considerations:

- Differentiation of knob shape and position. (*Errors have included confusing speed and heading knobs on the mode selector panel.)*
- Design to support correct selection of target values. (*Use of a single control (e.g., concentric controls) for selecting multiple command reference targets has resulted in erroneous target value selection.)*
- Commonality of control design across different aircraft to prevent negative transfer of learning with respect to operation of the controls. *(Activation of the wrong thrust function has occurred due to variation of TOGA and autothrust disengagement function between airplane types- negative transfer of learning with respect to operation of the controls.)*
- Positioning of individual FGS controls, FMAs, and related primary flight display information so that, as far as reasonably practical, items of related function have similarly related positions. (*Misinterpretation and confusion have occurred due to the inconsistent arrangement of FGS controls with the annunciations on the FMA.)*
- Design to discourage or avoid inadvertent operation; e.g., engagement or disengagement.

9.2 Flight Guidance Mode Selection, Annunciation, and Indication

Engagement of the Flight Guidance System functions should be suitably annunciated to each pilot, as described in Section 8, Flight Guidance System Engagement, Disengagement, and Override. The FGS mode annunciations should effectively and unambiguously indicate the active and armed modes of

operation. The mode annunciation should convey explicitly, as simply as possible, what the FGS is doing (for active modes), what it will be doing (for armed modes), and target information (such as selected speed, heading, and altitude) for satisfactory flight crew awareness.

Mode annunciation should indicate the state of the system and not just switch position or selection. Mode annunciation should be presented in a manner compatible with flight crew procedures / tasks and consistent with the mode annunciation design for the specific aircraft type (i.e., compatible with other flight deck systems mode annunciations).

Operationally relevant mode changes and, in particular, mode reversions and sustained speed protection, should be clearly and positively annunciated to ensure flight crew awareness. Altitude capture is an example of an operationally relevant mode that should be annunciated because pilot actions may have different effects on the airplane. Annunciation of sustained speed protection should be clear and distinct to ensure flight crew awareness. It should be made clear to the pilot if a mode has failed to arm or engage (especially due to invalid sensor data). FGS sub-modes (e.g., sub-modes as the FGS transitions from localizer capture to localizer track) that are not operationally relevant need not be annunciated.

In-service experience has shown that mode annunciation alone may be insufficient (unclear or not compelling enough) to communicate mode changes to the flight crew, especially in high workload situations. Therefore, the safety consequences of the flight crew not recognizing mode changes should be considered. If necessary, an appropriate alert should be used.

Mode annunciations should be located in the forward field of view (e.g., on the primary flight display). Mode selector switch position or status is not acceptable as the sole means of mode annunciation. Modes and mode changes should be depicted in a manner that achieves flight crew attention and awareness. Aural notification of mode changes should be limited to special considerations. Colors, font type, font size, location, highlighting, and symbol flashing have historical precedent as good discriminators, when implemented appropriately. The fonts and font size should be chosen so that annunciation of FGS mode and status information is readable and understandable, without eye strain, when viewed by the pilot seated at the design eye position.

Color should be used in a consistent manner and assure compatibility with the overall use of color on the flight deck. Specific colors should be used such that the FGS displays are consistent with other flight deck systems, such as a Flight Management System. The use of monochrome displays is not precluded, provided that the aspects of flight crew attention and awareness are satisfied. The use of graphical or symbolic (i.e., non-textual) indications is not precluded. Implementation of such discriminators should follow accepted guidelines as described in applicable international standards (e.g., AC/AMJ 25-11) and should be evaluated for their consistency with and integration with the flight deck design. Engaged modes should be annunciated at different locations and with different colors than armed modes to assist in mode recognition. The transition from an armed mode to an engaged mode should provide an additional attention-getting feature, such as boxing and flashing on an electronic display (per AC/AMJ 25-11) for a suitable, but brief, period (e.g., ten seconds), to assist in flight crew awareness.

The failure of a mode to engage/arm when selected by the pilot should be apparent. Mode information provided to the pilot should be sufficiently detailed, so that the consequences of the interaction (e.g., ensuing mode or system configuration that has operational relevance) can be unambiguously determined. The FGS interface should provide timely and positive indication when the flight guidance system deviates from the pilot's direct commands (e.g., a target altitude, or speed setting) or from the pilot's pre-programmed set of commands (e.g., waypoint crossing). The interface should also provide clear indication when there is a difference between pilot-initiated commands (e.g., pilot engages positive vertical speed and then selects an altitude that is lower than the aircraft altitude). The default action taken by the FGS should be made apparent.

The operator should be provided with appropriate description of the FGS modes and their behavior.

9.3 Flight Guidance Alerting (Warning, Caution, Advisory, and Status)

Alerting information should follow the provisions of §/JAR 25.1322 and associated advisory material. Alerts for FGS engagement and disengagement are described in Section 8, Flight Guidance System Engagement, Disengagement, and Override.

There should be some method for the flight crew to determine and monitor the availability or capability of the Flight Guidance System (e.g., for dispatch), where the intended operation is predicated on the use of the FGS. The method of monitoring provided should take account of the hazard resulting from the loss of the autopilot function for the intended operation.

9.3.1 Alerting for Speed Protection

To assure crew awareness, an alert should be provided when a sustained speed protection condition is detected. This is in addition to any annunciations associated with mode reversions that occur as a consequence of invoking speed protection (see Section 10.4, Speed Protection). Low speed protection alerting should include both an aural and a visual component. High-speed protection alerts need only include a visual alert component because of existing high-speed aural alert requirements, but does not preclude giving an earlier alert.

Alerting for speed protection should be consistent with the protection provided and with the other alerts in the flight deck. Care should be taken to set appropriate values for indicating speed protection that would not be considered a nuisance for the flight crew.

9.3.2 Loss of Autopilot Approach Mode

The loss of the approach mode requires immediate flight crew awareness. This may be accomplished through autopilot disengagement, as specified within AC 120-28D. If the autopilot remains engaged and reverts to a non-approach mode, an appropriate aural warning and/or visual alert should be provided.

9.3.3 Awareness of Potential Significant Transient Condition ("Bark before Bite")

There have been situations where an autopilot is engaged, operating normally, and controlling up to the limit of its authority for an extended period of time, and the flight crew was unaware of the situation. This service experience has shown that, without timely flight crew awareness and action, this situation can progress to a loss of control after autopilot disengagement, particularly in rare normal or non-normal conditions. However, with adequate flight crew awareness and pilot action, loss of control may be prevented.

To help ensure crew awareness and timely action, appropriate alert(s) (generally caution or warning) should be provided to the flight crew for conditions that could require exceptional piloting skill or alertness for manual control following autopilot disengagement (e.g., significantly out of trim). The number and type of alerts required would be determined by the unique situations that are being detected and by the crew procedures required to address those situations. Any alert should be clear and unambiguous, and be consistent and compatible with other flight deck alerts. Care should be taken to set appropriate thresholds for these alerts such that they are not considered a nuisance for the flight crew.

Situations that should be considered for an alert include:

Sustained Lateral Control Command: If the autopilot is holding a sustained lateral control command, it could be indicative of an unusual operating condition (e.g., asymmetric lift due to icing, fuel imbalance, asymmetric thrust) for which the autopilot is compensating. In the worst case, the autopilot may be

operating at or near its full authority in one direction. If the autopilot were to disengage while holding this lateral trim, the result would be that the airplane would undergo a rolling moment that could possibly take the pilot by surprise. Therefore, a timely alert should be considered to permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement which might result from the condition..

Sustained Longitudinal Out of Trim: If the autopilot is holding sustained longitudinal trim, it could be indicative of an unusual operating condition (e.g., an inoperative horizontal stabilizer) for which the autopilot is compensating. If the autopilot were to disengage while holding this longitudinal trim, the result would be that the airplane would undergo an abrupt change in pitch that could possibly take the pilot by surprise. Therefore, a timely alert should be considered to permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement which might result from the condition.

Bank and Pitch Angles Beyond Those Intended for Autopilot Operations: Most autopilots are designed with operational limits in both the pitch and roll axes, such that those predetermined limits will not be purposely exceeded. If the airplane exceeds those limits, it could be indicative of a situation (which may not be covered by items 1. or 2.) that requires the pilot to intervene. Therefore, a timely alert should be considered to bring this condition to the attention of the flight crew to and permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement which might result.

It is preferable that the autopilot remains engaged during out-of-trim conditions. However, if there is an automatic disengagement feature due to excessive out-of-trim, an alert should be generated and must precede any automatic disengagement with sufficient margin to permit timely flight crew recognition and manual disengagement. See also Section 8.4, Flight Crew Override of the FGS, for related material.

> **NOTE:** This section is not intended to require alerting for all instances of automatic autopilot disengagement. It is intended only for conditions, which, if not addressed, would lead to such disengagement which, could result in a significant transient for which the pilot may be unprepared. The intent is to provide crew awareness that would allow the flight crew to be prepared with hands on controls and take appropriate corrective action before the condition results in a potentially hazardous airplane configuration or state.
>
> **NOTE**: This section describes alerting requirements for conditions resulting in unintended out-of-trim operation. There are FGS functions that can intentionally produce out-of-trim operation (e.g. parallel rudder operation in align or engine failure compensation modes, pitch trim operation during the approach/landing to provide trim up/flare spring bias, or pitch trim operation for certain types of Speed/Mach trim systems). It is not the intent of this section to require alerts for functions producing intentional out-of-trim conditions. Other system indications (e.g., mode and status annunciations) should be provided to make the crew aware of the operation of these functions where appropriate.

9.4 FGS Considerations for Head-Up Displays (HUD)

Head-up displays (HUD) have unique characteristics compared to flight displays installed on the instrument panel. Most of these HUD differences are addressed during HUD certification whether or not the HUD provides flight guidance functions. The intent of this section is to address how such HUD differences may affect FGS functions.

9.4.1 Characteristics of HUD Guidance

If the HUD is designed as a supplemental use display system, it does not replace the requirement for standard Head Down Display (HDD) of flight instrument data. The HUD is intended for use during takeoff, climb, cruise, descent, approach and landing under day, night, VMC and IMC conditions. When

it can be reasonably expected that the pilot will operate primarily by reference to the HUD, it should be shown that the HUD is satisfactory for manually controlling the airplane and for monitoring the performance of the FGS system.

During take off and landing in certain light and visibility conditions, HUD symbology can be extremely dominant in comparison to external visual references. When visual references are relatively dim, extremely active symbology dynamics and guidance cue gains can lead the pilot to make excessively strong corrections. It should be shown that if HUD guidance cues are followed, regardless of the appearance of external visual references, they do not cause the pilot to take unsafe actions.

Generally the criteria for the mechanization of guidance displayed on the HUD would be no different than guidance displayed on the head-down display. See Section 10, Performance of Function, for flight director performance criteria.

However, unlike head-down displays, HUD's are capable of displaying certain symbology conformal to the outside scene, including guidance cues. Consequently, the range of motion of this conformal symbology, including the guidance, can present certain challenges in rapidly changing and high crosswind conditions. In certain cases, the motion of the guidance and the primary reference cue may be limited by the field of view. It must be shown that, in such cases, the guidance remains usable and that there is a positive indication that it is no longer conformal with the outside scene. It must also be shown that there is no interference between the indications of primary flight information and the flight guidance cues. In take off, approach, and landing FGS modes, the flight guidance symbology should have priority.

Additionally, HUD guidance is often used in cases, like the low visibility approach, where the pilot will need to reference both the information displayed on the HUD and outside references. Consequently, it must be shown that the location and presentation of the HUD information does not distract the pilot or obscure the pilot's outside view. For example, it would be necessary for the pilot to track the guidance to the runway without having the view of runway references or hazards along the flight path obscured by the HUD symbology.

9.4.2 HUD Flight Guidance System Display

The HUD display should present flight guidance information in a clear and unambiguous manner. Display clutter shall be minimized. The HUD guidance symbology should not excessively interfere with pilots' forward view, ability to visually maneuver the airplane, acquire opposing traffic, and see the runway environment. Some flight guidance data elements are essential or critical and should not be removed by any de-clutter function.

9.4.3 Head-Up/Head-Down Display Compatibility

The HUD FGS symbology should be compatible and consistent with symbology on other FGS displays such as head-down EFIS instruments. The FGS-related display parameters should be consistent to avoid misinterpretation of similar information, but the display presentations need not be identical. The HUD and head-down primary flight display formats and data sources need to be compatible to ensure that the same FGS-related information presented on both displays have the same intended meaning.

While not all information displayed on the HUD is directly related to the FGS, the pilot is likely to use most of the displayed information while using the HUD-displayed guidance and FGS annunciations. Therefore, when applicable, the guidelines below for the presentation of FGS-related display information should be followed as much as possible. Certain deviations from these guidelines may be appropriate due to conflict with other information display characteristics or requirements unique to head-up displays. These may include minimization of display clutter, minimization of excessive symbol flashing, and the presentation of certain information conformal to the outside scene.

(a) Symbols should be the same format (e.g., a triangle-shaped pointer head-down appears as a triangle pointer head-up; however, some differences in HUD symbology such as the flight director "circle" versus head-down flight director "bars" or "wedge" have been found acceptable);

(b) Information (symbols) should appear in the same general location relative to other information;

(c) Alphanumeric readouts should have the same resolution, units, and labeling (e.g., the command reference indication for "vertical speed" should be displayed in the same foot-per-minute increments and labeled with the same characters as the head-down displays);

(d) Analog scales or dials should have the same range and dynamic operation (e.g., a Glideslope Deviation Scale displayed head-up should have the same displayed range as the Glideslope Deviation Scale displayed head-down, and the direction of movement should be consistent);

(e) FGS modes (e.g. autopilot, flight director, autothrust) and status state transitions should be displayed on the HUD, and except for the use of color, should be displayed using consistent methods (e.g., the method used head-down to indicate a flight director mode transitioning from armed to captured should also be used head-up); and

(f) Information sources should be consistent between the HUD and the head-down displays used by the same pilot.

(g) When FGS command information (i.e., flight director commands) are displayed on the HUD in addition to the head-down displays, the HUD depiction and guidance cue deviation "scaling" needs to be consistent with that used on the head-down displays. This is intended to provide comparable pilot performance and workload when using either head-up or head-down displays.

(h) The same information concerning current HUD system mode, reference data, status state transitions, and alert information that is displayed to the pilot flying on the HUD, should also be displayed to the pilot not flying using consistent nomenclature to ensure unambiguous awareness of the HUD operation.

9.4.4 Alerting Issues

Although HUD's are typically not intended to be classified as integrated caution and warning systems, they may display warnings, cautions, and advisories as part of their FGS function. In this regard, HUD's should provide the equivalent alerting functionality as the head-down primary flight display(s). Warnings that require continued flight crew attention on the PFD also should be presented on the HUD (e.g., TCAS, Windshear, and Ground Proximity Warning annunciations). If master alerting indications are not provided within the peripheral field of view of the pilot while using the HUD, the HUD must provide annunciations that inform the pilot of Caution and/or warning conditions. [ARP-5288, V12]

For monochrome HUD's, appropriate use of attention-getting properties such as flashing, outline boxes, brightness, size, and/or location are necessary to adequately compensate for the lack of color normally assigned to distinguish and call attention to Cautions and warnings.

For multi-color HUD's, the use of red, amber, or yellow for symbols not related to Caution and warning functions should be avoided, so that the effectiveness of distinguishing characteristics of true warnings and cautions is not reduced.

Single HUD installations rely on the fact that the non-flying pilot will monitor the head-down instruments and alerting systems, for failures of systems, modes, and functions not associated with primary flight displays.

Dual HUD installations require special consideration for alerting systems. It must be assumed that both pilots will be head-up simultaneously, full, or part-time, especially when the HUD is being used as the primary flight reference, or when the HUD is required equipment for the operation being conducted.. If master alerting indications are not provided within the peripheral field of view of each pilot while using the HUD, then each HUD must provide annunciations that direct the pilot's attention to head-down alerting displays. The types of information that must trigger the HUD master alerting display are any Cautions or warnings not already duplicated on the HUD from head-down primary displays, as well as any Caution level or warning level engine indications or system alerts.

> **NOTE:** The objective is to not redirect attention of the pilot flying to other display when an immediate maneuver is required (resolution advisory, windshear).

If a Ground Proximity Warning System (GPWS), wind shear detection system, a wind shear escape guidance system, or a Traffic alert and Collision Avoidance System (TCAS) is installed, then the guidance, warnings and annunciations required to be a part of these systems, and normally required to be in the pilot's primary field of view, should be displayed on the HUD.

9.4.5 Upset/Unusual Attitude Recovery Guidance

Upsets due to wake turbulence or other environmental conditions may result in near instantaneous excursions in pitch and bank angles and a subsequent unusual attitude.

If the HUD is designed to provide guidance for recovery from upsets or unusual attitudes, recovery steering guidance commands should be distinct from, and not confused with, orientation symbology such as horizon "pointers." For example, a cue for left stick input should not be confused with a cue indicating direction to the nearest horizon. Guidance should be removed if cues become invalid at extreme attitudes, such as zenith, nadir, or inverted. For extreme attitudes it is acceptable to transition to the HDD, provided that the cues to transition from the HUD are clear and unambiguous.

If the HUD is designed to provide orientation only during upsets or unusual attitudes, cues must be designed to prevent them from being mistaken as flight control input commands.